A STUDY OF A WILSON'S CLOUD CHAMBER WITH LARGE SENSITIVE TIME AND OF ITS APPLICATION IN MEASURING RANGE OF α-PARTICLES EMITTED BY Pu^{239}

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Plate XVI

ABSTRACT. A brief description of a cloud chamber with long sensitive time has been given. Three different methods of determination of sensitive time have been described. The range of particles emitted from a specimen supposed to contain Pu^{239}, has been determined.

A Wilson cloud chamber was constructed with a large sensitive time in order to photograph tracks of ionising particles emitted during events of rare occurrence. In the present instance, the object of investigation was the measurement of the track length of α-particles emitted from a precipitate supposed to contain transuranic elements. The precipitate was separated by Dr. S. D. Chatterjee from a sample of uranite, a very old uranium containing mineral. The U_{238} portion of the uranium by absorption of cosmic neutrons or neutron produced during spontaneous fission of U_{235}, is expected to produce transuranic elements according to the following reaction

$$U^{238} + n_0^1 \longrightarrow U^{239} \xrightarrow{\beta^-} Np^{239} \xrightarrow{\beta^-} Pu^{239}$$

Pu^{239} is an α-particle emitter, with a half life of 24000 years. The sample supplied was of such feeble radioactivity, that ordinary ionisation method was not sensitive enough to detect its activity. When the sample after dissolution was spread over photographic emulsion C_2 of Ilford, several tracks could be observed on developing the plate after two weeks exposure. It was thought worthwhile to use a portion of the sample as a source of α-particles to measure their track lengths in the Wilson cloud chamber, and by comparison with the track lengths of α-particles emitted under identical conditions from a polonium source in the same cloud chamber, to determine the track length of the unknown source under standard conditions of temperature and pressure, and if possible from such measurements to identify its origin.

In Table I, we give the energy and range of α-particles emitted from Pu^{239} and from two other α-particle emitter of approximately the same

TABLE I

Source	Energy of α-particles in Mev.	Range in cms at 15°C-760 mm of Hg	Half life
$_{84}Po^{210}$	5.298	3.842	140 days
$_{94}Pu^{239}$	5.144	3.675	24000 yrs.
$_{90}Rd.\ Th^{228}$	5.335	3.88	1.9 yrs.

track lengths. The aim of our investigation by the method employed was (1) to establish whether the precipitate supplied was α-emitter, and (2) if so, to establish the identity of the emitting source from the range of the α-particles measured.

The present paper contains a description (*i*) of the Wilson cloud chamber of long sensitive time constructed in the workshop of the Institute, (*ii*) of the methods used to determine the sensitive time during expansion and the pressure variation within the chamber and (*iii*) of the method used for measuring the length of the α-particle tracks emitted by the given precipitate in terms of that from polonium.

(*i*) *Cloud Chamber.*—The diameter of the chamber is 15 cms., depth 2 cms., expansion is produced by the displacement of a movable diaphragm closing the lower side of the chamber ; the latter consists of a brass plate fixed at the centre of a rubber diaphragm. The rubber sheet is attached by means of the plate to a lever actuated by a cam and which is put under compression by a suitable steel spring. The under side of the diaphragm is filled with water on which a circular block of paraffin floats, such that the upper side of the paraffin is on a line with the water level—in fact, during expansion very little air current is produced.

The sensitive time is prolonged by producing first a rapid expansion to attain the necessary degree of supersaturation, and then to maintain the degree of supersaturation by further slow expansion. This end was achieved by cutting the slope of the cam controlling the expansion as shown in the diagram (Fig. I*a*) ; simultaneous with the movement of the diaphragm, air in the lower chamber gets compressed, so a flow of air takes place through the orifice of the stopcock producing a prolongation of the state of supersaturation as desired. To produce the desired effect, opening of the stopcock needs adjustment [figure of the Chamber and manometer, Figs. (*a*) and (*b*)].

A detailed study of the change of pressure was made by a manometer as described below. The accompanying figure (Fig. I*b*) gives a detail of the manometer which is attached to the cloud chamber. A small circular rubber membrane is cemented to the end of a side tube connected with the manometer and a small mirror M movable about axis X has its other end resting on the centre of the rubber membrane : a beam of light reflected from the

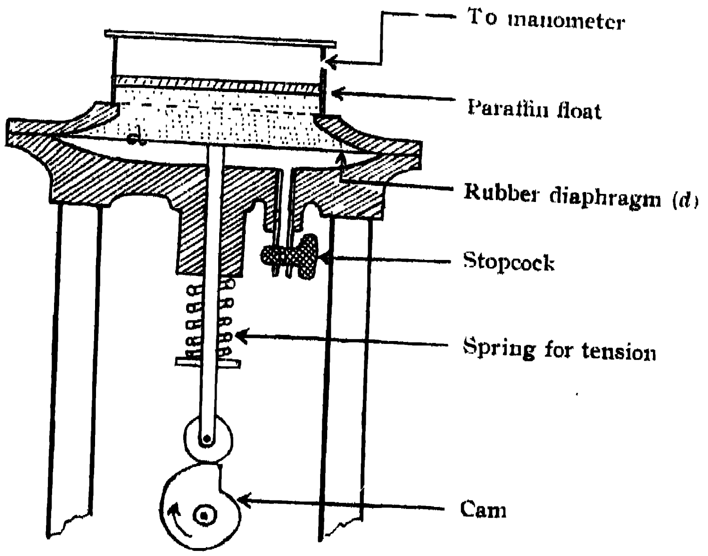

FIG. 1(*a*)

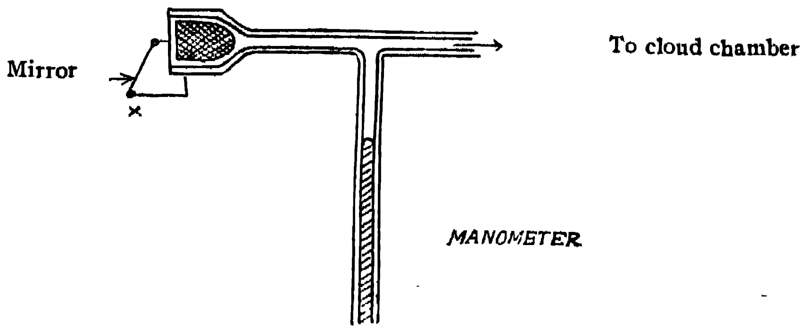

FIG. 1(*b*)

mirror falls on a scale placed at a distance of about 3 metres from the mirror, in order that a small change in the pressure in the expansion chamber may be determined with fair degree of accuracy. With this arrangement, a relative change of pressure up to about one per cent of the total change which was about 20 cms. of Hg could be determined. It may be added that we are not interested in the absolute value of the pressure at different moments, but only on the variation of pressure as the expansion progressed. The image of the spot of light is photographed with a standard Cine camera taking 24 pictures per sec. on a 35 mm film, thus changes of pressure can be observed at intervals of 0.04 sec. It may be argued that as there is a time lag between the pressure attained within the chamber and that indicated by the motion of the rubber membrane attached to the manometer, the latter does not, therefore, record the actual pressure in the chamber at the time of record. The lag being a constant common factor, the motion of the spot of light does give a true picture of the change of pressure with time, within the chamber. A plot of the time variation of the image or the spot of light has been given in Fig. 2.

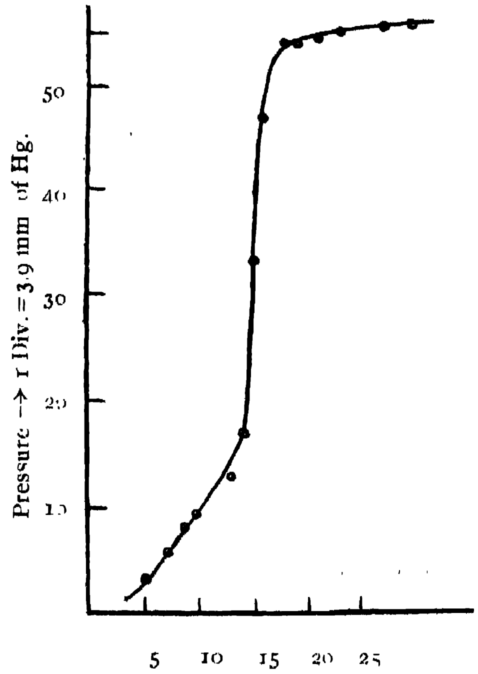

FIG. 2

(*ii*) *Sensitive time*.—The study of sentitive time has been described in a paper by Hazen (1942) where details about the sensitive time and its dependence on various factors has been fully discussed; here only the relevant points in the paper are discussed and utilized.

The sensitive time can be increased by (1) increasing the time for completion of the expansion and (2) also by increasing the ratio of the volume to the surface of the cloud chamber. Time duration of the expansion must be of the same magnitude as the sensitive time before the latter is appreciably lengthened. In our case, this condition is fulfilled as the time duration has been lengthened by the arrangement already described above; in addition, by increasing the ratio of volume to surface i.e. by using chamber of greater depth, the sensitive time can be increased; but then it is not possible to illuminate the whole depth of the cloud chamber; in our case the ratio of volume to the surface was, slightly greater than unity.

Actual period over which the state of supersaturation persisted was measured by three independent methods, each method yielding a sensitive time of about one second.

(*a*) In the first method a simple experimental device is adopted for roughly estimating the sensitive time of the cloud chamber. A weak radioac-

Fig. a.

Stereo-picture of α-particle emitted from Pu^{239}.

Fig. b.

Stereo-picture of a diffuse long-range α-particle track, possibly emitted from the other isotope of Pu. Only one picture was recorded out of about 8000 photographs.

tive source is placed inside a massive block of lead, 10 cms. from the could chamber; the lead block contains a cylindrical hole of 0.5 cm. diameter; in front of this lead block a massive lead wheel, 4 cms. thick, revolves slowly at a rate of 1 revolution in 11.5 secs. The rotating wheel contains a 4 mm hole and the wheel is so oriented that in a complete revolution the hole in the wheel comes once in line with the hole in the block of lead. On the wheel there is a graduation at intervals of 5° marking with o, the position of alignment of the two holes.

Operation for expansion was started by rotating the handle attached to the cam controlling the motion of the diaphragm of the cloud chamber, for different possitions of the wheel with respect to the fixed o mark, named as the point of observation in the Fig. 3. Thus o in the table shows that the operation starts when holes are in alignment, expansion corresponding to 5° means that after 0.16 sec. alignment occurred between two holes, and so on.

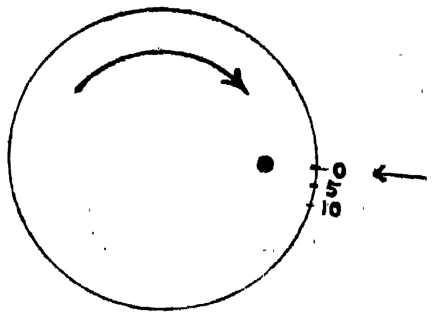

FIG. 3(*a*)

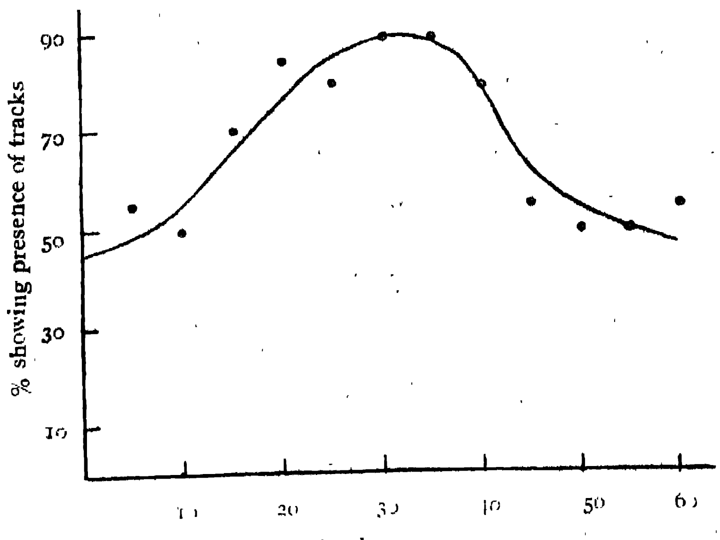

FIG. 3(*b*)

Table II, along with the graph, shows that for an angular width of about 25° on the lead wheel, the chamber must have remained in a state for receiving the impression of ion trails. Now, 25° on the lead wheel corresponds to 0.8 sec.—the sensitive time of the cloud chamber.

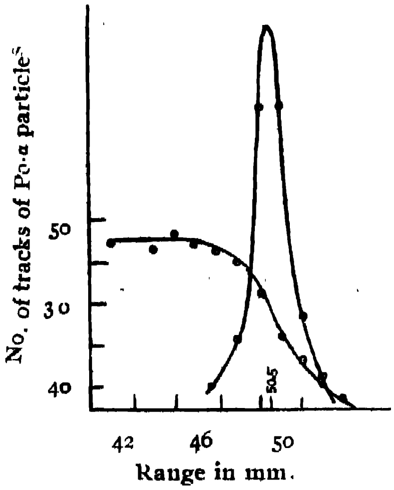

Fig. 4

TABLE II

Angle in degrees	Percentage of total expansion giving the presence of tracks
0	45
5	55
10	50
15	70
20	85
25	80
30	90
35	90
40	80
45	55
50	50
55	50
60	55

(*b*) In the second method, the sensitive time was estimated from the cinematographic picture extending over the period taken to perform the act of expansion; photographs are taken of several expansion at the rate of 24 pictures per sec. During the course of one of the expansions, two different tracks at different places in the chamber were observed after an interval of 20 pictures; this observation leads to the conclusion that during above period at least the chamber must have remained sensitive. It was noticed that the number of droplets formed per c.c. in the expanded volume was never more than 1 or 2 on an average; a larger number of droplets per c.c. generally shortens the sensitive time by denuding the volume of supersaturated vapour by causing a growth in the size of the droplets at the expense of the state of supersaturation.

(*c*) In the third method, William's formula, connecting the sensitive time and the number of cosmic particles recorded per expansion, was utilized in finding the sensitive period of the chamber. Average number of cosmic ray tracks per expansion is given by the expression

$$t_s . j . x . d$$

where j is about 0.03—number of cosmic particles per cm^2 per second.

d=diameter of the chamber in cm.

x=depth of illumination

t_s=sensitive time.

Observation extending over a thousand expansions revealed that on an average 0.5 was the number of cosmic ray track per expansion; since $d = 13$ cms., $x = 1$ cm., on substitution, the sensitive time comes out to be a little over one second.

(*iii*) *Measurement of length of α-particle tracks.*—The main objective for the construction of this chamber was to find the range of the α-particles emitted from a precipitate extracted from an uranium ore of Indian origin and supposed to contain plutonium 239. Usually a very small quantity of Pu is found to be present in the ore. In the method of separation employed Pu was extracted with a rare earth tracer from the ore; a small fraction of the extract was smeared on the surface of a brass disc placed inside the chamber. The content of Pu on the specimen was so small that out of 2,000 photographs taken, only 36 tracks of α-particles emitted from the source were obtained; amongst them were some tracks which were diffused and some of them ended outside the region of illumination.

Some of these tracks are reproduced in Plate XVI.

In order to obtain a correct length of the tracks, the stereoscopic pictures were built up in space with the same camera arrangement used for photographing them under identical conditions. By this method the lengths of α-particle tracks as built up in space were determined.

TABLE III

Range in mm.	No, of particles
43	44
44	45
45	43
46	47
47	44
48	42
49	40
50	32
51	21
52	16
53	10
54	6

Similarly, a large number of photographs of tracks of α-particles emitted from polonium source were taken under identical conditions. These tracks were also built up in space and from the measurement of their lengths an estimate of the average track length was obtained by using the above method.

A comparison of this average length of α-particle track from Po as deduced from graph was made with the length of the longest Pu α-track. (FIG. 4).

This method was found necessary since total number of plutonium α-particle tracks were only 88. With such a meagre number, extra-polation was not possible without incurring a large amount of statistical error. (*vide* Plates)

The results on measurement of the track lengths are given below:

Average range of Po-α = 50.5 mm.

Maximum range of Pu-α = 46 mm.

Whence the range of Pu-α = 3.5 cms. under normal conditions.

The range thus determined gives a value smaller than that found by other authors, but as no other α-particle of this range have been observed for α-particle emitting sources belonging to the three principal radioactive series occurring in nature, the observed particles may be attributed to Pu^{239}. In the Radio Chemical laboratory of the Institute, attempts are being made to isolate this element from a larger quantity of pitchblende obtained from Canada. When the isolated precipitate is ready the investigation with the Wilson chamber will again be resumed.

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